Observations on the Structure of Far Northern New Zealand

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Abstract.

Evidence is presented for the occurrence of two epochs of compression in northern North Auckland Peninsula since the Middle Tertiary, in the first of which the pressure was directed from north and south, while in the second it was from east and west.

East-west fold axes due to north-south compression are important in the region north of the Bay of Islands. A later system of tear faults extends from North Cape to the west head of Whangaroa Bay, coinciding with the belt of intrusion and mineralization recognised long ago by Hector, and is thought to be related to compressive force from east and west.

Such successive foldings at right angles have already been indicated by Lillie in other parts of New Zealand, particularly as an alternative to Macpherson's supposed swinging strike in the Waiapu district.

The idea that fold axes strike north-west in the Far North is not confirmed, except in so far as the whole New Zealand Ridge may represent a geanticline.

INTRODUCTION.

The structural interpretation of the North Auckland Peninsula has long been a matter of uncertainty. Two main ideas have been proposed. The first, which was, in general, held by the Old Geological Survey, is that the trend of the Peninsula is not that of the fold axes but was determined by later fractures. This view was adopted by Benson in 1924. The other proposal was that the trend of the Peninsula does reflect that of the fold axes, and was held tentatively by Ferrar (1927) on the basis of a few observations of strike in the older rocks. Bartrum and Turner (1928) supported this view, being apparently largely influenced by the north-west trend of "foliation" in the gabbro at North Cape. While this second hypothesis may be correct in so far as the New Zealand Ridge as a whole represents a geanticline, it is felt that to draw a group of north-west-trending anticlines and synclines throughout the length of the Peninsula, as has been done by Macpherson (1946), may be misleading.

DIRECTIONS OF FOLD AXES.

Study of the available information on the Far North (north of the Bay of Islands) suggests that we have here fold axes running between west-south-west and west-north-west, oblique to the length of the North Auckland Peninsula.

Of this large region the North Cape area is perhaps the best known. A map, compiled from the work of McKay (1894) and Bartrum and Turner (1928), is presented to show the available information on the dip and strike and distribution of the beds there (fig. 1). Two points about the map call for comment: (1) McKay showed andesitic conglomerate extending over the area marked as Cretaceous, between the two question marks and east-south-east of them. Bartrum and Turner found Cretaceous lavas in this area, but patches of andesitic conglomerate are shown flanking the Cretaceous, for it is very probable that McKay had some basis for his opinion, while Bartrum and Turner examined only exposures adjacent to the track from Te Paki to Te Hapua. (2) The beds around the northern and western shores of Parengarenga Harbour were placed *below* the andesitic conglomerate by McKay. Bartrum and Turner, however, place them above the conglomerate, for conglomerate emerges from beneath them in low cliffs on the north shore of the harbour, and this later conclusion is here adopted.

The recorded dips and the distribution of the beds suggest very strongly that there is a system of folds trending about west-north-west in the North Cape area. Data on the attitude of the Cretaceous lavas and sediments are scanty, but the strike observed at Pandora suggests that the long straight coast between Spirits Bay and Te Reinga may be a strike coast. The youngest beds recorded as affected by this folding are the sandstones, mudstones and grits (t3) which immediately overlie andesitic conglomerates dated as Miocene (Altonian) (Couper, 1952).

A second map (Pl. 49) covers the area between North Cape and Whangaroa Harbour on the east and Herekino River on the west. In the south-eastern part of this region Bell and Clarke (1909) infer the existence of two anticlinoria of late Palaeozoic to Triassic beds, the more southerly, inland one running west-south-west and the other, further north, on the coast east of Whangaroa Harbour, running west-north-west. Westwards, the geology is not well known and we are dependent mainly upon McKay's map of 1894. There appear to be two massifs of older rocks, of unknown age, lying in an east-west line south of Kaitaia. They comprise much igneous material, partly intrusive and probably partly ancient lava flows. They may in part be Cretaceous in age and comparable with the Cretaceous lavas of the North Cape area. This is believed to be true of lavas, pillowy in part, around Mangonui, in the south-east corner of Doubtless Bay, for these lavas, on the coast at Taipa, appear to be conformable with the Cretaceous beds in the lower part of Taipa River; but no boundary can yet be drawn between these supposedly Cretaceous lavas and any older rocks that may be present.*

The 1948 Geological Map of New Zealand, published by the Geological Survey, subdivides McKay's Cretaceo-Tertiary formation in a broad way, into beds of Cretaceous (Mata) and Tertiary (Landon) age, with a strip of rocks of Arnold age east of Kaitaia and some Wanganui beds in Victoria Valley. These distinctions are very valuable and serve to show the general trend, between west-south-west and due west, of the axes of folding in the area between Reef Point and Whangaroa Harbour. In Taipa River (south shore of Doubtless Bay) the strike of the Cretaceous beds is east and west, the dip south at moderate to high angles, for a mile across the strike.

In Rangiawhia Peninsula (Battey, 1950) two main formations are present, breccia, conglomerate and grits standing vertical, striking west

* It is well known, on definite evidence from other parts of North Auckland, that contemporaneous lavas occur in both Permian and Cretaceous parts of the marine sedimentary sequence.

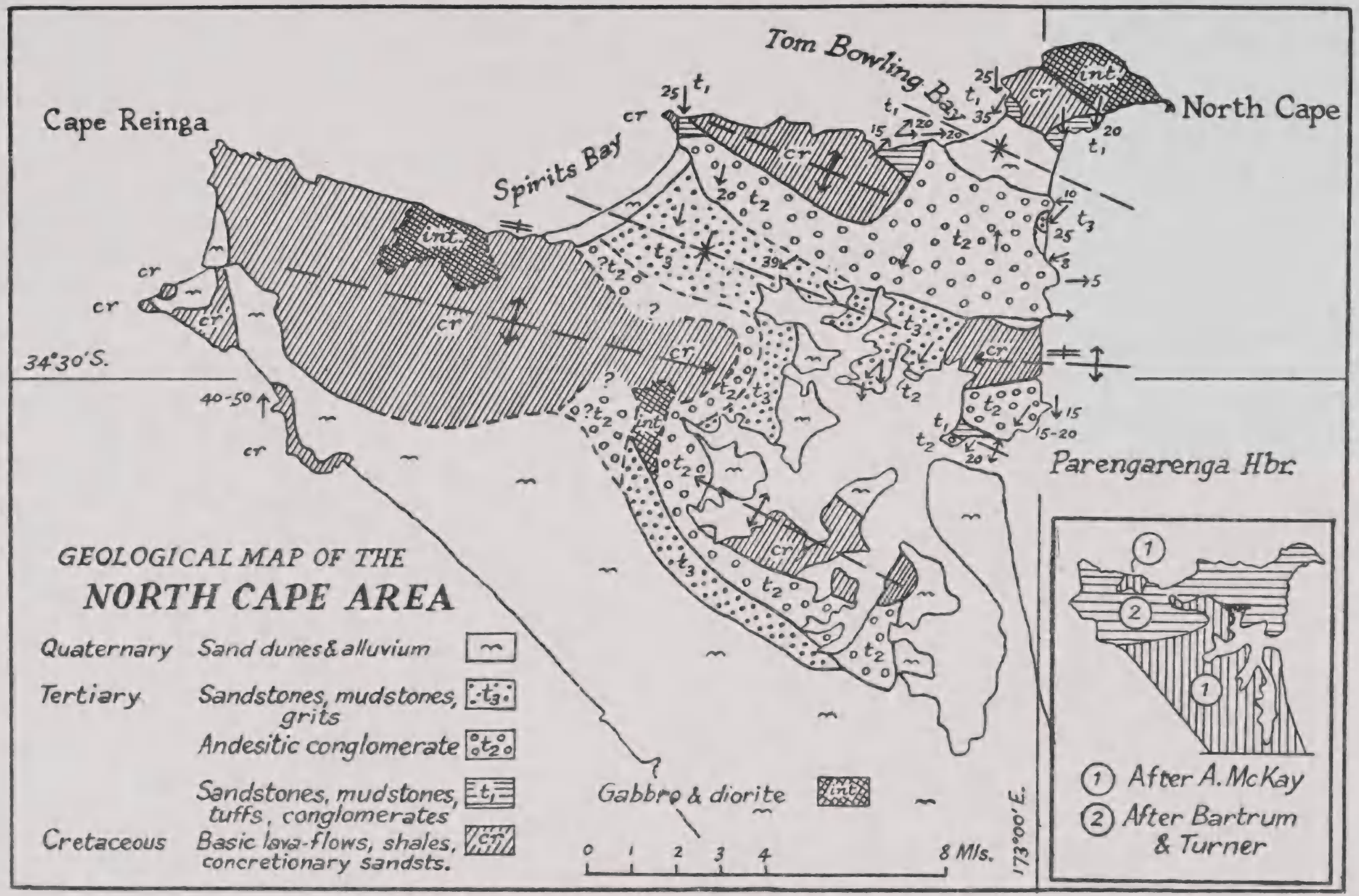
GEOLOGICAL MAP OF THE
NORTH CAPE AREA
Cape Reinga
Spirits Bay
Tom Bowling Bay
North Cape
Parengarenga Hbr.
34°30′S.
173°00′E.
Quaternary
Sand dunes & alluvium
Tertiary
Sandstones, mudstones, grits
Andesitic conglomerate
Sandstones, mudstones, tuffs, conglomerates
Cretaceous
Basic lava-flows, shales, concretionary sandsts.
Gabbro & diorite
0 1 2 3 4 8 Mls.
1 After A. McKay
2 After Bartrum & Turner

Fig. 1.

and younging south along the south-east coast, which rest unconformably upon a group of basic pillow lavas and keratophyres, in which a roughly westerly strike is inferred from correlation of pillow lava bands and from topographic expression of the main keratophyre horizon. Neither group is satisfactorily dated, but there are some grounds for referring the extremely heavy conglomerates (with included graphic granite boulders 9ft. across) to the same transgression as the conglomerates at the base of the Cretaceous succession at Whangaroa (also with granitic pebbles) recorded by Bell and Clarke (1909).

In Mount Camel (fig. 2), to the west-north-west, both basic pillow lavas and keratophyres similar to those of Rangiawhia occur, and from the distribution of characteristic types of keratophyre a strike about N85°W is inferred. For this whole group of pillow lavas and keratophyres the name Mt. Camel formation, used by Bell and Clarke (1910) is convenient. In passing it may be noted that a very similar group of rocks builds the western part of Great Island in the Three Kings Group. It seems reasonable to regard the Mt. Camel formation at Rangiawhia and Mt. Camel as representing an anticlinal axis.

To sum up, we seem to have fold axes striking west-south-west forming an eastward-pointing V with west-north-west folds in the south, an east-west group in the angle of the V, and a dominance of the west-north-west trend in the north. Broadly speaking, we can regard these folds as due to compression from north and south, or north-north-east and south-south west.

TRANSCURRENT FAULTING.

This fold system is cut across obliquely by a fault system running between N30°W and 40°W along the north-east coast, with which is associated a large dyke-like intrusion of gabbro and diorite with subsidiary andesite dykes. This zone was recognised long ago by Hector (1891) as extending from North Cape through Rangiawhia Peninsula and Stephenson's Island to Cape Brett. He pointed it out in connection with the mineralization that has taken place at points along its course. In 1894 Hector described the antimony prospects in the Cape Brett area and records a general trend of N40°W for the stibnite lodes in that south-eastern extension of the zone.

Mapping at Rangiawhia has shown that there the faults of this system are tear faults (transcurrent faults) with sinistral displacement (i.e., north-westward movement on the north-east sides of the planes) with an aggregate horizontal shift of at least 2¼ miles, distributed over a belt of country 3¼ miles wide (Battey, 1950, with maps).

This faulting is later than the folding of the upper Cretaceous rocks (with *Aucellina*) which are intruded by the associated igneous rocks and sheared by the movements at Pa Island on the west shore of Whangaroa Bay (see also the Survey 1 inch map of 1909).

It is to the stress system associated with this transcurrent faulting and multiple dyke-injection that the north-westerly foliation in the North Cape gabbro must be ascribed. The new data thus necessitate a revision of the view of Bartrum and Turner (1928) that this mineralogical banding is due to folding about north-westerly axes, and removes one of the principal criteria on which this interpretation of the structure was based.

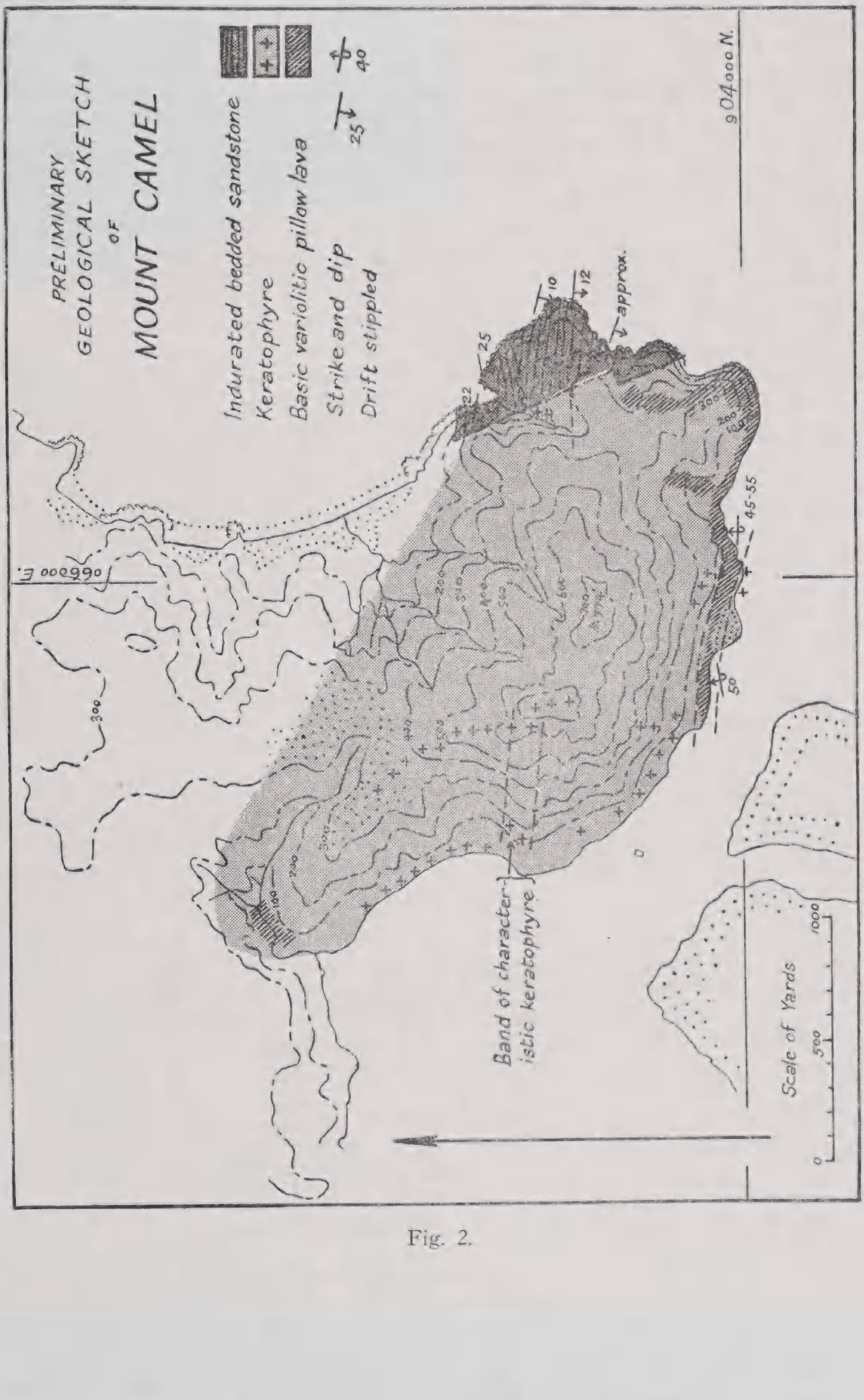
PRELIMINARY
GEOLOGICAL SKETCH
OF
MOUNT CAMEL
Indurated bedded sandstone
Keratophyre
Basic variolitic pillow lava
Strike and dip
Drift stippled
25
40
904000 N.
966000 E.
10
12
approx.
25
22
45-55
50
Band of character-
istic keratophyre
Scale of Yards
0
500
1000

Fig. 2.

MECHANICS OF FAULTING.

The directions of the sub-vertical dykes associated with this movement, and regarded as occupying fissures produced by it, may be expected to give information about the nature of the forces involved. Measurements of these directions and of the directions of very steeply-dipping joints in the intrusive rock have been made, chiefly at Rangiawhia. Both kinds of measurement show the same direction-frequencies and the two sets combined have been plotted as a direction-frequency diagram (Pl. 49). This diagram shows equal maximum concentrations in the azimuth-groups N40-45°W and N25-30°W. Two other equal concentrations lie between N85°W and W and N5°E and N. A pair of much less marked concentrations occurs at N50-55°E and N60-65°E, that is at 95° and 90° to the N40-45°W and N25-30°W groups respectively.

These directions can, on the whole, be explained remarkably well in terms of the stress theory of the rupture of homogeneous bodies in compression, as outlined by Wilson (1947) and applied (to a problem somewhat similar to the present one) by Blyth (1950), but there remain some uncertainties in interpretation. If compression acted from north and south the northerly fractures could be explained as tension cracks, but the westerly ones remain unexplained. If compression acted from east and west, the westerly cracks can be regarded as tensional but the northerly ones cannot be explained. In the field both kinds are filled by dykes in the country rocks and in the main body of the intrusion. Those of the westerly group are perhaps more marked and it is noteworthy that east-west dykes occur over a rather wide area. There is a relatively big one at Taipa River mouth on the south shore of Doubtless Bay, which is quarried. It is 100 feet wide and can be followed eastwards for three-quarters of a mile. At Pa Island (west shore of Whangaroa Bay) there is another conspicuous one, and another at Tupou Bay to the west-north-west.

If the stress ellipsoid is orientated with maximum pressure from a shade east of north and west of south, the main north-west shear directions fit slightly better the theoretical locus of stress shear planes, than if maximum pressure from just north of east and south of west be assumed.

What may decide the issue is the sinistral sense of the movement on the faults along the Rangiawhia coast. Sinistral movement on a north-west-striking transcurrent fault apparently implies east-west compression. If the pressure were from north and south the movement would be dextral. This seems to be a rather rigid requirement of the theory. For this reason we are apparently compelled to assume east-west compression. If we could postulate more or less north-south compression we should be able to explain the folds already described, and the subsequent tear faulting, as due to the one system of compressive forces. As it is, it seems necessary to assume first a north-north-east—south-south-west compression to produce the folds, followed by compression from east and west to explain the tear faults.

This demand is not a new one, for Lillie (1951, pp. 236-8) has recently postulated a similar abrupt change in the directions of compression to explain the way in which folds in the Tertiary strata run almost at right angles to those in the Cretaceous rocks in the Waiapu area, and has found evidence of similar happenings in the south of the South Island. His hyphothesis may prove to have rather wide application.

It may be remarked in connexion with the Rangiawhia fault pattern that a fault striking about N55°E runs along the south-east coast of the Peninsula between tide marks. It is older than the north-west faults and is shifted by them. Nothing definite is known of the type of displacement along it, but its direction may suggest that it is a conjugate fracture of the same stress system as produced the north-west-striking tear faults.

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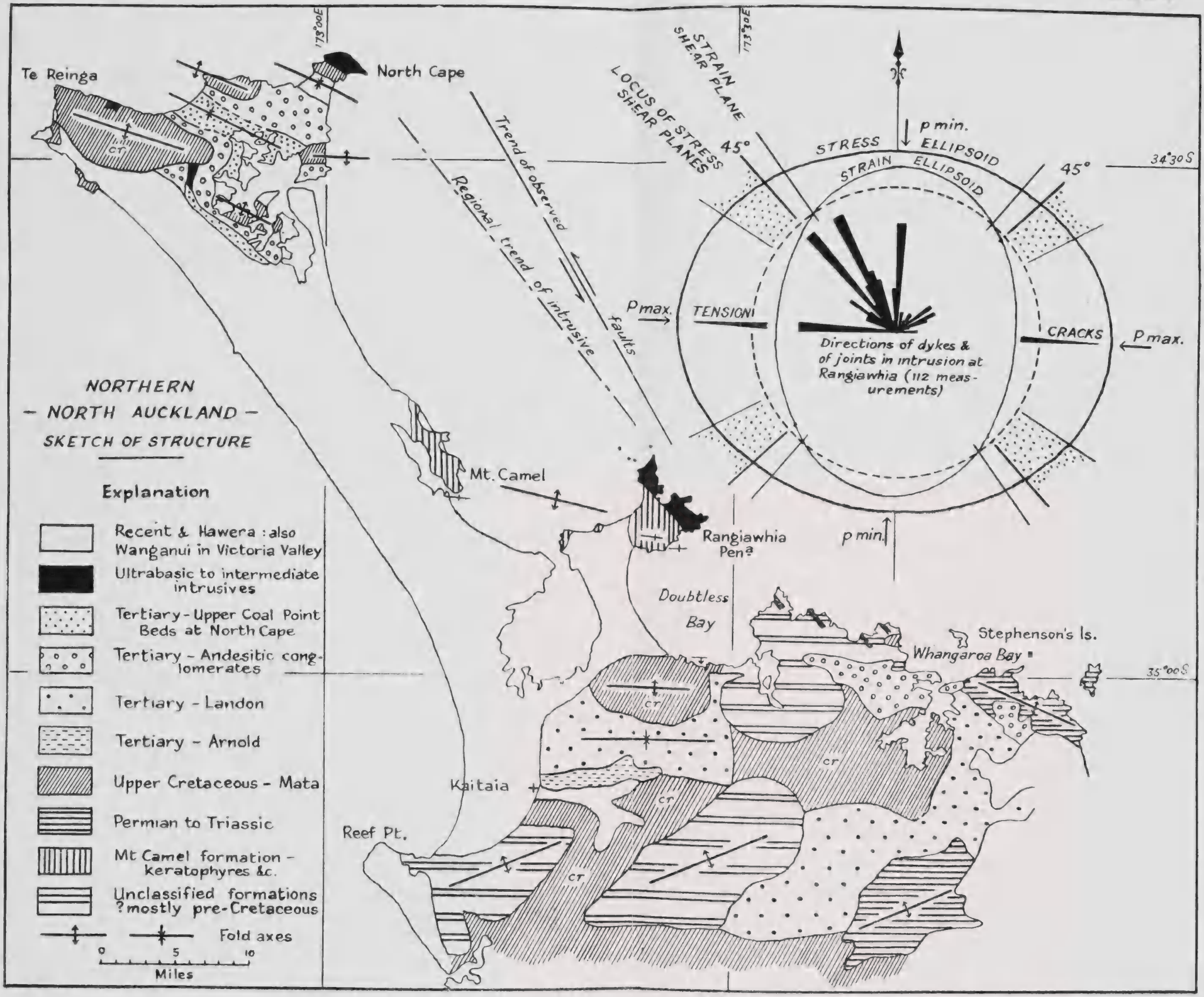
NORTHERN
- NORTH AUCKLAND -
SKETCH OF STRUCTURE
Explanation
Recent & Hawera : also Wanganui in Victoria Valley
Ultrabasic to intermediate intrusives
Tertiary - Upper Coal Point Beds at North Cape
Tertiary - Andesitic conglomerates
Tertiary - Landon
Tertiary - Arnold
Upper Cretaceous - Mata
Permian to Triassic
Mt Camel formation - keratophyres &c.
Unclassified formations ?mostly pre-Cretaceous
Fold axes
0 5 10
Miles
Te Reinga
North Cape
173°00'E
173°30'E
34°30'S
35°00'S
Trend of observed faults
Regional trend of intrusive
LOCUS OF STRESS SHEAR PLANES
STRAIN SHEAR PLANE
45°
45°
p min.
STRESS ELLIPSOID
STRAIN ELLIPSOID
P max.
TENSION
CRACKS
P max.
Directions of dykes & of joints in intrusion at Rangiawhia (112 measurements)
p min.
Mt. Camel
Rangiawhia Penª
Doubtless Bay
Stephenson's Is.
Whangaroa Bay
Kaitaia
Reef Pt.
CT